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Ashes and abs: testing calcium in gladiator tonic

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Travel back to ancient Rome, test the calcium content of a gladiator recovery drink and compare it to today's milk and sports drinks. History has never tasted this real!

This is a hands-on experiment that blends Roman history, nutrition science, and analytical chemistry. The activity supports cross-curricular learning in:

- **Analytical chemistry:** acid-base titration, complexometric analysis, and use of indicators
- **Nutrition science:** dietary sources of calcium, bioavailability, and historical versus modern nutrition
- **History of science and medicine:** Roman daily life, ancient diets, and historical practices in sports and health
- **Experimental methods:** lab safety, quantitative analysis, and scientific reasoning

It also fosters key competences such as critical thinking, data interpretation, and interdisciplinary connections.

Educational level recommendation

This proposal can be adapted for different ages and curricula. It is designed to connect a practical chemistry experiment (complexometric titration of calcium in plant ashes) with historical and nutritional perspectives. A complexometric titration is a type of chemical analysis in which metal ions, such as calcium, are measured by forming stable complexes with a reagent, most commonly EDTA (ethylenediaminetetraacetic acid, is a reagent that binds calcium ions at a one-to-one ratio, enabling quantitative measurement).

One of our goals is to bridge the gap between disciplines that are often kept apart, even though they have much more in common than we usually think.

- **Ages 14–16:** At this level, it is best to use the activity as a teacher-led demonstration followed by a class discussion. Students can explore the calcium content of ashes compared to milk, reflect on bioavailability, and make connections with the lifestyle and diet of Roman gladiators. The experiment can be further simplified into a qualitative comparison instead of a full titration. For example, students can observe turbidity when a sodium carbonate solution is added to different samples (ash tonic, milk, water) or explore the formation of alginate ‘calcium spheres’ as a visual indicator of calcium presence. These adaptations allow the same core idea: testing calcium availability with minimal equipment and safe reagents.
- **Ages 16–18:** At this level, students can carry out the full laboratory protocol, including EDTA titration and quantitative analysis. They can also perform an optional correction for magnesium interference.

An ancient drink and a modern experiment

In ancient Rome, gladiators were known as the sports superstars. Imagine a mix between football legends, MMA champions, and action movie heroes. Most were prisoners of war, slaves, or criminals, but even free men and fallen aristocrats could end up training in the ludus, the gladiator school. They spent long hours training outdoors, often in the sun, and followed a strict diet known as gladiatoria sagina. It was rich in carbs, surprisingly low in meat, and mostly plant based.

Why? Because they needed endurance, not just muscle. Their goal was to fight long, hard battles and recover fast.



Relief with gladiators

Image: [Yale University Art Gallery](#), [CCO 1.0](#)

But there was a surprising ingredient in their recovery routine: plant ash. Pliny the Elder (1st century AD) quotes the scholar Varro, who recommended a mixture of hearth ash and water to heal internal injuries. He notes that gladiators used this remedy after combat.^[1]



Culinary Juniper ash

Image courtesy of the author

A 2014 study of gladiator remains from Ephesus (Turkey) revealed that they had denser bones than the average Roman. Chemical analysis of the bones showed high levels of strontium, which is likely from plant-based minerals such as ash.^[2] Researchers suggest that they drank an ash tonic, possibly mixed with vinegar and water to create a mildly alkaline drink, similar to an early sports drink. The vinegar also helped purify the water in a time without sanitation.^[3]

Interestingly, other cultures used similar strategies. Across the ocean, the Navajo and Hopi peoples add juniper ash to traditional dishes as a source of calcium, which is especially useful for people with lactose intolerance. Just one gram of juniper ash contains as much calcium as a glass of milk!^[4]

Now it's time to put the science to the test. In this lab activity, you'll recreate the gladiator's ash drink and use titration to measure its calcium content. Was ash truly the secret behind the Roman's strength?

Activity 1: Ash to action – the chemistry behind Roman strength

The estimated duration for the complete activity is 90 min, the duration is shorter (approximately 60 min) if it is carried out as a teacher demonstration.



Safety notes

- The experiment should be performed under a fume hood when handling corrosive acids that release vapors.
- All students should wear safety goggles, gloves, and a lab coat.
- Always add acid to water, never water to acid, to prevent splashing.
- Samples should be heated in a water bath inside the fume hood to avoid inhaling harmful vapors.
- Skin that has come into contact with acid should be rinsed immediately with plenty of water. Students should inform the teacher.
- Make sure that students do not taste any substance or touch their mouth or eyes during the experiment.

Materials

- 1 g of plant ashes
- 1 M hydrochloric acid (HCl)
- Distilled water
- 0.01 M EDTA solution
- Buffer solution pH 10
- Eriochrome Black T (EBT) indicator
- Beaker
- Volumetric flask
- Graduated cylinder
- Pipette
- Burette
- Funnel
- Filter paper
- Safety equipment (gloves, goggles, lab coat)
- [Activity 1 Worksheet](#)

We used clean shifted culinary juniper ash from ancient, reclaimed juniper wood (*Juniperus communis*) produced by Rimal Apothecary. This is the same type of ash traditionally used by the Navajo in their ancestral dishes. For classroom use, students may use ashes from other clean, untreated plant sources, such as oak, beech, hazel, olive wood, or even from natural fertilizer ash. If the ash is not certified as food-grade, it must not be consumed under any circumstances.

A buffer solution keeps the pH constant, ensuring that the color indicator works properly during titration. An indicator changes color at the endpoint of the titration, showing when all calcium ions have reacted with EDTA.

Procedure

1. Weigh 1 g of plant ash and transfer it into a beaker.
2. Add 25 ml of 1 M HCl and stir gently.
3. Heat the mixture in a water bath under a fume hood until the ashes are fully dissolved.
4. Filter the solution and collect the clear filtrate in a 250 ml volumetric flask. Fill up to the 250 ml mark with distilled water.
5. Transfer 5 ml of this solution into a clean beaker and add 10 drops of the buffer solution (pH 10) and 2–3 drops of the EBT indicator.
6. Titrate with EDTA (0.01 M) solution until the color changes from violet-red to pure blue.
7. Record the volume of EDTA used. Calculate the calcium content, bearing in mind that, with EBT at pH 10, the titration measures Ca^{2+} and Mg^{2+} (See section below).



Experimental setup

Image courtesy of the authors

Note on accuracy:

According to published data,^[5,6] juniper ash intended for human consumption contains approximately 280–300 mg of calcium per gram and a considerably lower amount of magnesium (around 18 mg/g). Therefore, in this protocol, the result obtained at pH 10 with EBT is interpreted as primarily calcium, while acknowledging that magnesium may cause a slight overestimation. Magnesium can be excluded optionally by repeating the titration at $\text{pH} \geq 12$ using Murexide as the indicator.

Formula to convert the EDTA volume into calcium concentration:

$$\text{mg of calcium/g of ash} = (V_{\text{EDTA}} - 1.48 \text{ ml}) \times 20.04 \text{ mg/g ml}$$

- V_{EDTA} represents the volume of 0.01 M EDTA used in the titration (ml).
- The factor 20.04 converts ml of EDTA into mg of calcium per g of ash, based on the dilution scheme (1 g ash diluted in 250 ml → taking a 5 ml aliquot).

- The subtraction of 1.48 ml corrects for the average magnesium content ($\approx 18 \text{ mg/g}$ ash from literature). Omitting the correction results in a measurement that represents the content of calcium and magnesium rather than calcium alone.

Results

To analyse the outcome of your titration, use the calcium in ashes table provided in the [Activity 1 worksheet](#) to compare and interpret your results. This will help you understand how the calcium content in your sample relates to published values.



Juniperus communis (common juniper), the plant used to produce the culinary ash in the experiment.

Image: Ivar Leidus/Wikimedia Commons, CC BY-SA 4.0

Discussion

After completing the experiment, discuss the following questions in small groups or as a class. Use historical context, scientific reasoning, and modern nutritional knowledge to support your answers. An [example answers sheet](#) is provided in the supporting materials.

1. Could a handful of ashes really match a glass of milk?

Use your experimental results to compare the calcium content in the ash tonic with milk or sports drinks. What did your data suggest?

Complete the table below with reference values or your results.

Sample	Calcium content	Equivalent to milk
Milk	120 mg/100 ml	–
Plant ashes		

- Which contains more total calcium: milk or ash?
- Why is total calcium not enough to determine which is better for your bones?
- Is it better to get calcium from supplements or from

natural foods? Justify your answer based on what you've learned.

2. Is calcium from ashes as bioavailable as the calcium in milk?

Bioavailability describes how much of a nutrient your body can actually absorb and use. Even if some foods are rich in nutrients, your body may not be able to easily access them.

- What factors help or block calcium absorption in the body?
(Hint: Think about vitamin D, other minerals, or the chemical form of the calcium.)
- Do you think your body can easily absorb calcium from ash? Why or why not?
- Does milk contain the same type of calcium as ash? Which one might be better absorbed and why?

3. Strategies to improve calcium absorption

Before answering, you'll need to read the introduction text again carefully. Three subtle hints are hidden in the way gladiators ate, trained, and prepared their drink. These clues can help you understand how they might have improved calcium absorption.

Think of three possible strategies gladiators could have used to absorb more calcium from their diet:

Are any of these strategies still used today? Think of some examples.

4. Would you drink an ash tonic after a workout?

- Would you try it once? Why or why not?
Justify your opinion.
- How do you think ancient people saw this type of drink compared to how we see functional or natural foods today?

5. What parallels can you find between Roman nutrition and today's sports culture?

Think about supplements, recovery drinks, daily routines, rituals, and how athletes manage their public image. Can you find modern equivalents to the gladiator ash drink?

Final reflections

Although ash contains high levels of calcium, milk and other natural foods provide forms of calcium that are more easily absorbed by the body. Bioavailability, not just quantity, is key. Gladiators may have boosted absorption through sun exposure, vinegar drinks, and intense training. These are strategies that are still used today.

Their ash tonic, once a trusted recovery drink, shares surprising parallels with modern sports nutrition. This highlights how ancient and modern athletes alike rely on science, culture, and even marketing to shape their diets. ‹‹

References

- [1] Quote of C. Plinius Secundus in his book *Naturalis historia* (XXXVI, book 2, chapter 2): <https://scaife.perseus.org/reader/urn:cts:latinLit:phi0978.phi001.perseus-lat2:20.2/?q=quidam%20adversus&qk=form>
- [2] Lösch S et al. (2014) [Stable isotope and trace element studies on gladiators and contemporary Romans from Ephesus \(Turkey, 2nd–3rd c. AD\) – Implications for differences in diet](#). *PLOS ONE* **9**. doi: 10.1371/journal.pone.0110489
- [3] Ash tonic and vegetarian diet of Roman gladiators: <https://www.sciencedaily.com/releases/2014/10/141020090006.htm>
- [4] Thesis on quantification and comparison of calcium in juniper ash and soil used in traditional Navajo foods: <https://openknowledge.nau.edu/id/eprint/4935/>
- [5] Information on harvesting and the nutritional value of indigenous foods: https://www.bie.edu/sites/default/files/documents/harvest_of_the_month_april_juniper_ash.pdf
- [6] Christensen NK et al. (1998) [Juniper ash as a source of calcium in the Navajo diet](#). *Journal of the American Dietetic Association* **98**: 333–334. doi: 10.1016/S0002-8223(98)00077-7

Resources

- Read this NIH [fact sheet on calcium](#).
- Discover simple adaptations of experiments to make chemistry accessible to students with vision impairment: Chataway-Green R, Schnepf Z (2023) [Making chemistry accessible for students with vision impairment](#). *Science in School* **64**.
- Try some activities to learn about drinking water and encourage sustainable habits: Bergamotti D, Semeghini P (2023) [What are you drinking? Tap water versus bottled water](#). *Science in School* **65**.
- Investigate the properties of so-called superfoods: Frerichs N, Ahmad S (2020) [Are ‘superfoods’ really so super?](#) *Science in School* **49**: 38–42.
- Read an introduction to microscale chemistry in the classroom: Worley B (2021) [Little wonder: microscale chemistry in the classroom](#). *Science in School* **53**.
- Recreate smells from more than 2000 years ago: Farusi G (2011) [Smell like Julius Caesar: recreating ancient perfumes in the laboratory](#). *Science in School* **21**: 40–46.
- Get students excited about eating greens and learning about nutrition: Voak H (2016) [From greens to genes: healthy eating and nutrition](#). *Science in School* **36**.
- Find out how what we eat can influence our epigenome: Florean C (2014) [Food that shapes you: how diet can change your epigenome](#). *Science in School* **28**: 34–45.
- Discover what energy drinks contain in the school lab: Thibault E, Biedermann K, Watt S (2017) [Cans with a kick: the science of energy drinks](#). *Science in School* **39**: 48–54.

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Rita Tasa is a biology and STEM teacher in secondary schools in Catalonia. Trained as a biochemist and with a strong international background, she is particularly interested in making science relevant through hands-on activities, real-world challenges, and cross-curricular projects. Her favourite moments in the classroom are when students connect scientific concepts with everyday life and start asking their own questions.

Irina Nanu is a Latin and Greek teacher in Barcelona. She is passionate about ancient Rome, historical storytelling, and computational linguistics. As a translator and copywriter, she specialises in medical content for organisations such as the WHO, national health departments, and pharmaceutical companies. She enjoys exploring the ancient world through the eyes and senses of the people who lived in it.

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